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CURRENT PRACTICES

CURRENT PRACTICES - SUBSURFACE DISPOSAL

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ABSTRACT

Review of the onsite wastewater system technology literature reveals a dearth of data on the occurrence and fate of pathogens. Similarly, in light of recent advances in the field of soil physics, the microbiological literature on the fate of pathogens in soils reveals that existing information is often less than helpful in an analysis of the potential transmission of these varieties. Consequently, an assessment of the potential pathogenic groundwater problems accruing from onsite wastewater treatment systems cannot presently be more than qualitative until better data are provided for the fate of organisms in the all-important unsaturated soil zone below the disposal system. Although the problems of the initial startup period for conventional onsite system designs can be qualitatively described, there is clearly a need to develop quantifying data through the joint efforts of microbiologists and soil scientists in order to provide the engineers and sanitarians with the health-related justification to improve onsite system designs.

Additional areas where data are sparse include the occurrence of pathogens in septic tank pumpings and their fate and effects through the handling, treatment and disposal of these residuals. Also, the quantification of the potential health risks due to the failure of soil absorption systems by surfacing is relatively undetermined.

Introduction

Since the earliest days of recorded history, man has demonstrated a continuing and growing desire to separate himself from his waste products. In early times this desire was based primarily on the offensive nature of wastes, but as knowledge of disease sources and transmission progressed, the desire proved to be well-founded as a means of minimizing the incidence of many, but not all, diseases.

Aimed with new confidence that improved sanitation techniques could control many formerly unavoidable diseases, the simplicity and effectiveness of

necessary to protect the public and the environment from pollution or are they the result of a bureaucratic rule-making machine gone wild?

The results of your deliberations during the course of this conference can make a substantial contribution to the Nation's quest for knowledge and in the shaping of decisions which will guide future activity in this subject area. I wish you well as you undertake the earnest debate that will shape your sessions, as you attempt to resolve honest differences of opinion that are sure to arise, and as you labor to reach the common consensus which undergirds our democratic process.

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the septic tank-soil disposal concept which both carried wastes safely from the home and disposal of them below the surrounding soil could be clearly appreciated. The application of this concept was limited by two factors extant prior to World War II. Since the concept was considered viable only where no sewers were available and it required continuous water supply and ability on demand which, in turn required electricity, the general lack of cheap electrical service in rural areas limited adoption. Also, the overall demographic trend of decreasing rural populations leaving the farm for jobs in the industrializing urban centers contributed to the modest growth in septic tank-subsoil disposal technology.

In the period immediately following World War II factors such as low-cost mortgage availability, sudden population booms, inadequate supply of housing, inexpensive and improved transportation, and relative prosperity resulted in housing demands both in areas surrounding urban centers and in more remote communities now served by modern electrical networks as a result of the electrification programs begun some years earlier. The resulting condition was a tremendous increase in the number of homes served by septic tank-subsoil disposal systems. The state and local authorities were ill-prepared to deal with these problems since they had minimal information on which to base the siting, design, construction, and maintenance of these facilities. The resulting concern for a major breakdown in the level of sanitation due to wholesale failures of these systems precipitated a major study by the Public Health Service to investigate the proper functioning of unsewered individual household wastewater sanitation systems. The results of this major research program served to significantly upgrade the state of knowledge on the siting, design, and maintenance of onsite wastewater disposal systems.

Although much of the information generated by these studies was incorporated into the ensuing document that has become a classic in this field, i.e., the Manual of Septic Tank Practice (1), the overall text of that document was not completely reflective of the Public Health Service uniform Manual of Septic Tank Practice (MSTP) did provide a national health code basis, which was wholly or partly incorporated by most state health departments into their codes. Although many clearly undesirable onsite system practices were eliminated by this procedure, the MSTP was by no means perfect; for example, it promoted the desirability of sewers as the only "permanent solution to wastewater disposal." However, the popular demand for further onsite wastewater system research was diminished for a substantial period as a result of the popular misconception that the MSTP contained "all the answers."

By the 1970's, a series of events were underway which caused renewed interest in onsite disposal systems. Major contributors were inflation and the initial saturation of large cities' demands for wastewater treatment facilities. This combination moved the plight of the smaller communities to the forefront of eligibility for federal funds. However, costs for traditional "preferred" solutions, i.e., conventional sewers and treatment methods, employed almost exclusively in larger cities were found to be prohibitive for these smaller communities, even with large federal and state subsidies. The first reaction to small community demands for solutions to wastewater contamination problems was to provide research and development

information on lower cost onsite alternatives and new sewerage technologies which could reduce the cost of abating problems caused by failing existing systems in smaller communities. Much of the improved onsite technology will be discussed later in these proceedings by Professor Boyle.

An additional aspect of this work has been devoted to better understanding of how conventional systems work, and why they fail to perform in the manner originally conceived, i.e., disposal which keeps the liquid waste below the ground surface and has minimal impact on the quality of underlying groundwater. Although some onsite system failures will undoubtedly always occur, the great majority are due to improper site evaluation, inadequate design, poor construction techniques, and little or no maintenance. In short, onsite wastewater treatment and disposal technologies are technically feasible, but have traditionally been improperly implemented. Despite this, it is not uncommon to find data which indicate systems have performed successfully anywhere from 20 to 40 years.

In order to satisfy the stated purpose of this discussion, i.e., description of current practices in onsite subsurface disposal, it was necessary to review an extensive body of microbiological information on the occurrence of various organisms, their characteristics and response to environmental conditions and, most importantly, removal data from field or laboratory simulations of field treatment and disposal systems. Upon completion of this review, in light of onsite technology advances, the need for this conference became quite clear. The prevailing literature does not provide the necessary data upon which public health decisions can be based with any reasonable certainty.

Source Characteristics

The role of conventional septic tank-soil absorption systems (ST-SAS's) in controlling the spread of pathogenic microorganisms and the fate of these organisms within the confines of this technology are difficult to define due to significant variations in state and local codes, in enforcement of those codes, and in the functioning of these systems in different soils. Figure 1 depicts a complete ST-SAS within its surroundings. In essence, wastewater generated in the household are conveyed via the building drain and sewer to the septic tank, where settling of heavier solids and flotation of lighter materials takes place. From the septic tank the partially treated wastewater flows to a subsurface disposal structure where the wastewater may infiltrate into the soil for further purification prior to incorporation into the groundwater below the site.

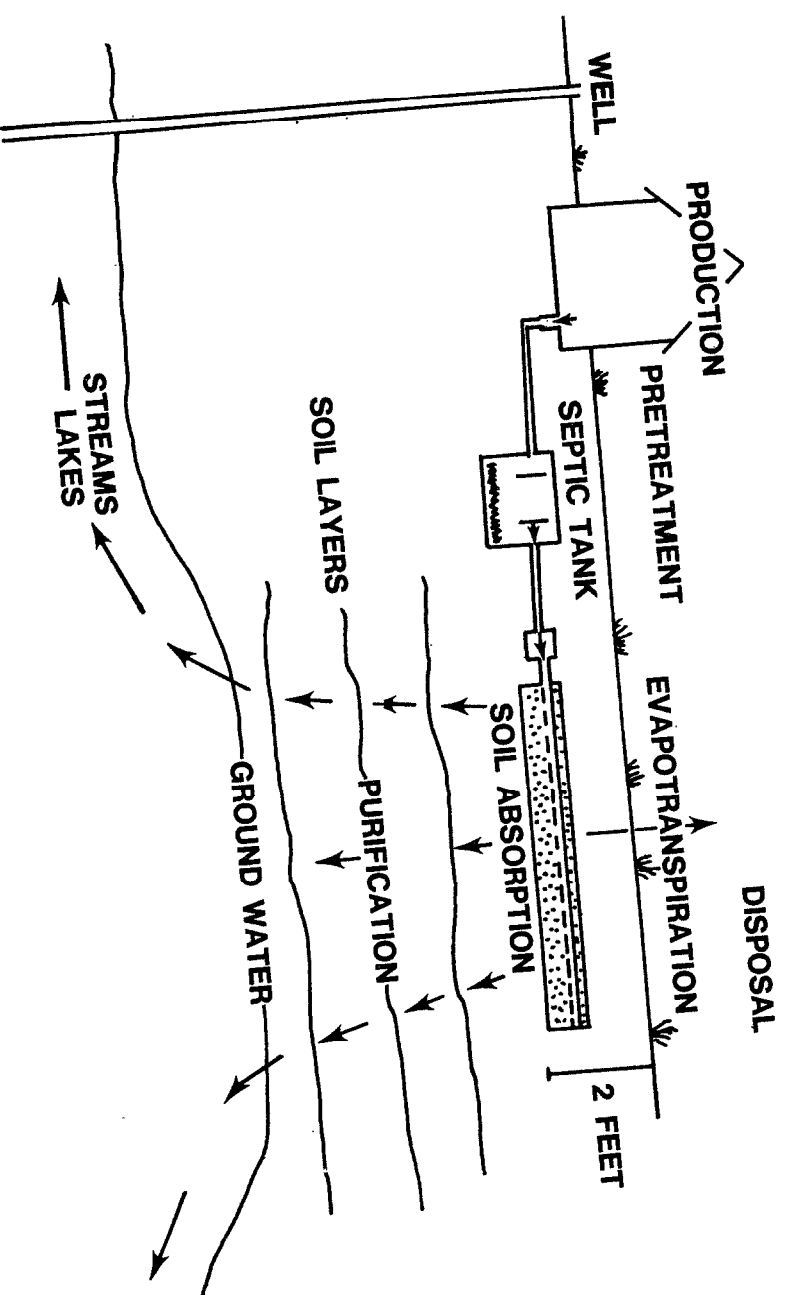


Figure 1. Soil Disposal of Septic Tank Effluent

As a first step to defining current practice, without regard for its fallacies or shortcomings, one needs to characterize the wastewater from the household served. Several investigators have recently analyzed parameters, and wastewaters in terms of flow, chemical and physical parameters, being that wastewaters in terms of flow, chemical, the most complete study being that of the University of Wisconsin (2). Unfortunately, there are relatively few data on specific pathogens in household wastewater should be noted, i.e., the presence of specific pathogens is less probable in household waste, i.e., the presence of specific pathogens is less normally be higher. Put in simpler terms, a particular endemic pathogen will usually appear in a municipal wastewaterers in low numbers, but will likely appear in a specific household wastewater only when one or more members of that household are actively shedding. The pathogen will likely be far less diluted than in the municipal system unless either a high percentage of the community is infected or the pathogen sources are not limited to human fecal discharges. However, once introduced to a septic tank, it may persist for some time.

Studies of several rural households for the pathogens *Salmonella* spp, *Pseudomonas aeruginosa* and *Staphylococcus aureus* were positive in 2 of 11, 10 of 10, and 4 of 10 families' wastewaters, respectively (3). Indicator

bacteria, as measured by fecal coliform and fecal streptococci tests were ubiquitous. Similarly, Green (4) reported that only one of several septic tank effluents was found to yield a positive test for virus (140 PFU/l), that being identified as a poliovirus 3 (Po-3). Recent California studies of composting toilets and graywater (non-toilet wastewater) systems isolated one *Salmonella* organism from 26 samples of 12 toilets, while 2 of 20 samples from 11 toilets yielded reovirus, and 26 samples from 12 toilets yielded one *Trichuris trichiura* ova (5). All compost toilet leachates analyzed were positive for nematode larvae and/or living flagellate and ciliate protozoa.

Therefore, the first questions to be answered are those pertaining to what organisms are present in household wastewaters, in what numbers and how do they respond to the environment of the septic tank? To the first question, in addition to Table 1, the literature sources report the potential presence of parasites *Ascaris*, *Hymenolepis*, *Trichuris*, *Toxocara*, *Taenia*, *Enterobius*, *Ancylostoma*, and other hookworm and nematode species as well as numerous bacteria and virus species. Of course, the number of these organisms in the household wastewater would vary widely from zero to very large numbers per liter when contributors become infected. Such quantitative numbers are somewhat scarce, but could be estimated by assuming a weight of feces excreted times the number of organisms per unit weight of feces from infected individuals, diluted by the daily wastewater flow from the dwelling.

Septic Tanks

A cutaway view of a single-compartment septic tank is shown in Figure 2.

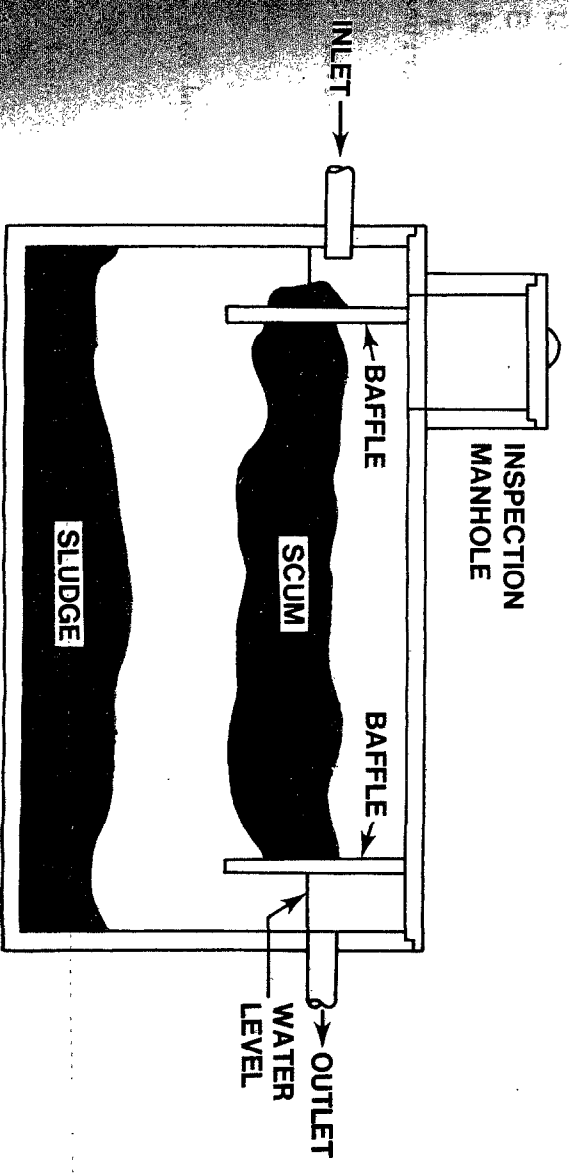


Figure 2. Single Compartment Septic Tank

3.8 cu m (500 and 1,000 gallon) sizes noted above, and an average family size of four persons. These assumptions would yield a nominal detention time of 2.5 to 5 days. The World Bank Report (6) notes that removals of pathogens in septic tanks are a function of detention time and organism reaction to the oxygen deficient conditions in the tank. Removals for all pathogens are given as 0 to 2 logs (0 to 99%). Howard and Lloyd (7) report 2 to 3 logs of removal of *Vibrio cholerae* in a two-stage tank receiving only toilet wastes with minimal flush volumes. Also, *V. cholerae* die-off under anaerobic conditions at 25 C was reported to be about 0.5 log/day. The World Bank Report indicates that *Leptospira* spp. normally survive only a few days in wastewater; *Salmonella* spp. removals approach 3-log removal (99.9%); *Shigella* spp. or multiple-compartment tanks may approach 3-log removal (99.9%); *Ascaris* ova were removed at nearly the same efficiency (82%) as suspended solids in a 1.5 m³ (400 gallon) septic tank treating blackwater with a nominal detention time of 20 days; only 65 percent of the hookworm ova were removed under the same conditions as *Ascaris* ova; settling rates of *Schistosoma* ova were shown sufficient to obtain at least 73 percent removal in two days; *Trichuris* ova had been shown to settle slower than other parasite ova; *Entamoeba histolytica* cysts were 98 percent removed in a cylinder and 56 percent removed in primary clarifiers at two hours nominal detention time; *Entamoeba histolytica* cysts were found to have a Stokes settling velocity of 0.007 to 0.11 meters/hr; *Ancylostoma* were found to be 60 percent removed in a series; and a septic tank and 98 percent removed by three Imhoff tanks in series; and a septic tank with three-day nominal detention time removed 99.4 percent of *Ascaris* ova with no effect from anaerobiasis. Some investigators (8) have reported minimal removals of virus by primary sedimentation. Green (4) prepared suspensions from feces containing poliovirus and found that shaking was sufficient to free 50 to 89 percent of the associated virus from the suspended solids. Subsequent attempts to estimate the amount of readorption in a septic tank yielded 18 and 45 percent readorption to solids with one hour of mildly-agitated contact.

In reviewing these widely scattered data, the only conclusion which can be reached is that the septic tank is unlikely to remove any organism, completely, and that septic tank effluent must be considered capable of transmitting any disease whose pathogenic agent appeared in the influent or wastewater. Some support for this conclusion has been provided by epidemiologists. During the period from 1970 to 1974, at least ten waterborne disease outbreaks in the United States have implicated septic tank systems (9-11). Five of these outbreaks were infectious hepatitis; two were shigellosis (*Shigella sonnei*); two were acute gastroenteritis of unknown origin; one was typhoid fever (*Salmonella typhosa*); and one was cholera (*Vibrio cholerae*). It should be noted that this number of outbreaks is less than 10 percent of the total number of outbreaks occurring during this period and that all confirmed ST-SAS causations, recommended separation distances were met or exceeded.

Soil Absorption Systems

The above conclusion provides reinforcement to the key role played by

the subsurface soil disposal system as the primary barrier to passage of pathogenic microorganisms into the environment. To understand the difficulty of describing current practices in this crucial area, Table 2 is presented.

TABLE 2. VARIABILITY OF STATE CODES

Setbacks (to wells, surface water)	11 -92 m	(35-300 ft)
Trench Spacing	1.8- 3.0 m	(6- 10 ft)
Trench Cover	0 - 0.3 m	(0- 12 in)
Min. Perc Rate	Yes-No	
Max. Perc Rate	12 -47 min/cm	(30-120 min/in)
Trench Width	0.3- 0.9 m	(12- 36 in)
Sizing	Soils-Perc Rate	

In addition to the varying code requirements described in this table, several other phenomena must be discussed before any analysis can be attempted. The unsaturated zone of soil below the bottom of the disposal system is the single most important factor in preventing transmission of pathogens. This zone provides physical straining, aeration/drying, adsorption potential and other physical and chemical factors which can maximize both removal and inactivation of pathogenic organisms. What is not shown in Table 2 is the widely varying and often inadequate site evaluation requirements of the state and local codes. Often these shortcomings minimize the effectiveness of the unsaturated zone from the initial moment of use, providing increased potential for pathogen transport to the groundwater or surface where the potential for human contact becomes more imminent and conditions are less suitable for removal.

In analyzing the performance of subsurface SAS's, the method of size determination and liquid distribution must be reviewed. Most states require the use of the percolation test both for determination of soil suitability and SAS sizing. The percolation test is depicted in Figure 4. The physical significance of this test has never been established, but its variability has (12)(13). Given the fact that most existing codes are based to some degree on the MSTP (1), the design sizes of that document are given in Table 3. The variability of a well-performed percolation test has been shown to be anywhere from 20 to 90 percent (12). Therefore, it could be assumed that field or SAS sizing could be in error by at least these percentages for a well-performed test, and possibly much more when the test is poorly performed in fine textured soils.

With a standard trench disposal system the following description is pertinent. In the initial few months of operation, a conventional system with gravity distribution and 10 cm (4-inch) pipe with multiple holes at or near

coliform) were always present at low temperature operation. With the silt loam columns, ponding developed at the 1 cm/day dosing rate in one month, thus eliminating passage of any of the fecal bacteria. One other silt loam column was found to have several large pores or channels which resulted in wholesale passage of all organisms tested, except S. aureus. Reducing the loading from 1 cm/day to 3 mm/day caused the liquid to penetrate the pedons within 30 days, thus eliminating the passage of fecal indicators.

Other investigators have reported information Kristiansen (15) reported nearly all pathogens in unsaturated soil. four logs of fecal coliform reduction in sand which had a clogging layer within 10 cm of the soil-trench interface, while 75 cm failed to remove undisturbed soils to determine travel of fecal coliforms below the SAS trenches. than one log in slightly clogged sand. Brown, et al (16), used three undisturbed soils to determine travel of fecal coliforms yielded positive fecal A sandy loam loaded at 8.2 cm/day ($2 \text{ gal/day}/\text{ft}^2$) while second year coliform samples 5 percent of the time 1.2 meters below the trench were negative first year of operation (mostly during initial startup), while second year positives were 2 to 3 percent. All samples after the second year large pores, due to natural cracks or root channels, caused high counts below the trenches tive. In the sandy clay loaded at 3.3 cm/day ($0.8 \text{ gal/day}/\text{ft}^2$) the trenches during the early days of operation, but fecal coliform counts returned at normal as crusting developed. With the clay soil loaded at 1.2 m 1.6 cm/day ($0.4 \text{ gal/day}/\text{ft}^2$), travel of fecal coliforms was negligible. In parallel studies with coliphage T₂, two of the 52 samples taken from 1.2 m below the trenches in the clay soil tested positive over a few days after These two samples that showed 4 logs of removal weretaken a few days after large coliphage doses were added to the dry (cracked) clay soil. Robeck et al. (17) obtained 3 to 4 logs of removal of Po-1 through rather uniform loading (once per day feeding). Gram (18) used sand of 0.25 mm effective size in 0.88 m (1.25 ft) of travel at 9.5 cm/day (20 to 40 gal/day/ ft^2) and once per day dosing at settled day (relatively uniform sand (e.s. = 0.53 mm)) and parasites from settled day (2.33 gal/day/ sq ft) to determine removals of parasitites from settled wastewater. It was noted that 0.3 m (1 ft) of sand was able to remove 3 logs of the 8 logs of Ascaris eggs applied with the first dose, and no eggs appeared in the effluent after four days. It was further noted that 0.61 m (2 ft) of sand removed all Ascaris and Nematode eggs and Entamoeba histolytica cysts applied through seven days of operation.

Ascaris and Nematodes stoma eggs were removed by the 0.61 m columns at 12.2 and 16.2 cm/day ($4 \text{ gal/day}/\text{ft}^2$). available, but after the tests are reviewed other not representative

shown in Figures 6 and 7 (19). Because of its relative uniformity of pore sizes, sand is the simplest soil to use in explaining the concept of contact time. From Figure 6 one can quickly note how a sand drains after all the pores have been filled with water. If, for example, one knows the average moisture content of a sandy soil and the nominal application rate, an average velocity may be computed by the following equation:

where: v' = average velocity (cm/day)

In sand with a $v = 5$ cm/day and $\theta = 0.09$, $v' = 56$ cm/day and contact time in each foot (30 cm) of unsaturated soil would be 30/56 days or 13 hours.

The contact time concept is consistent with observations of other reviewers (21) that pathogen removal passage through soil is due to both mechanical straining and adsorption processes. Maximizing contact time improves the effectiveness of both mechanisms. Also, increased contact time is directly related to soil dryness and both increased time and reduced moisture provide greater opportunities for inactivation of pathogens. If a necessary contact time for pathogen removal could be established by concerted efforts of microbiologists, soil scientists, and engineers, some rationality of design could be established for ST-SAS's to replace the "black art" status

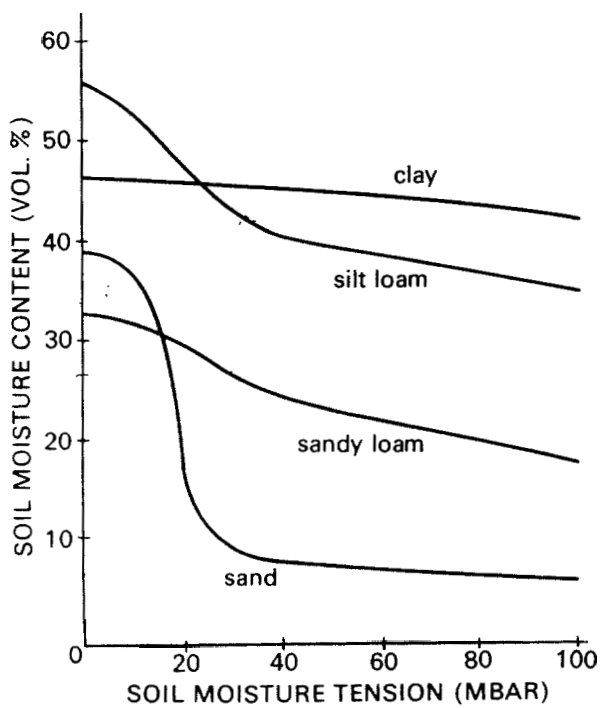


Figure 6. Moisture Retention Curves

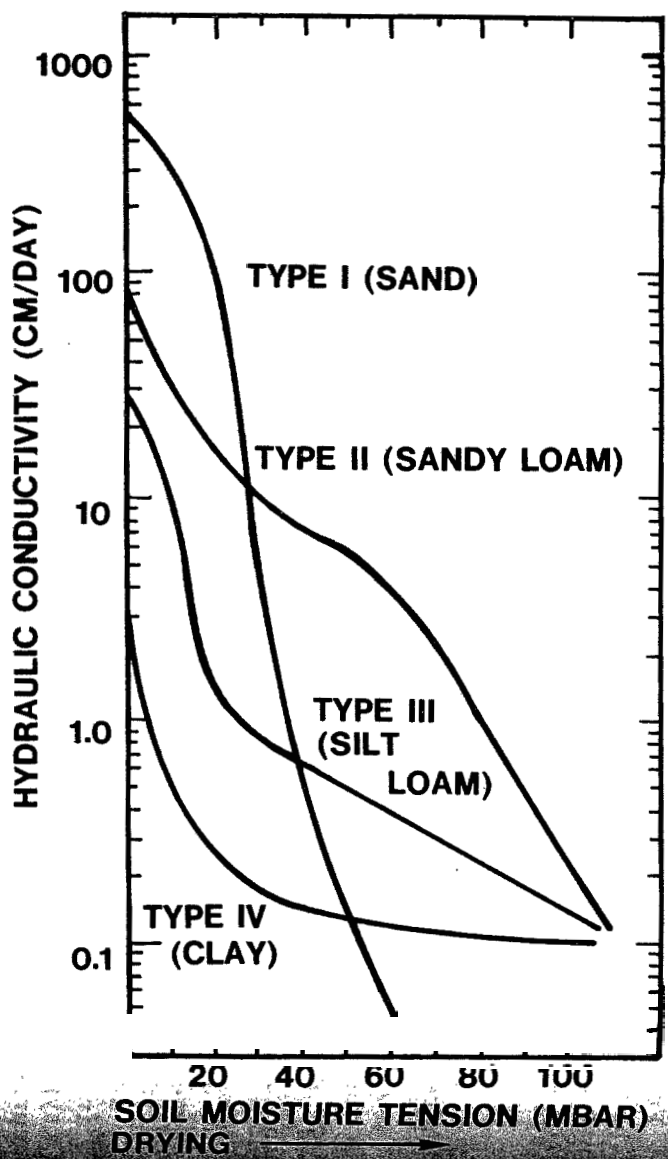
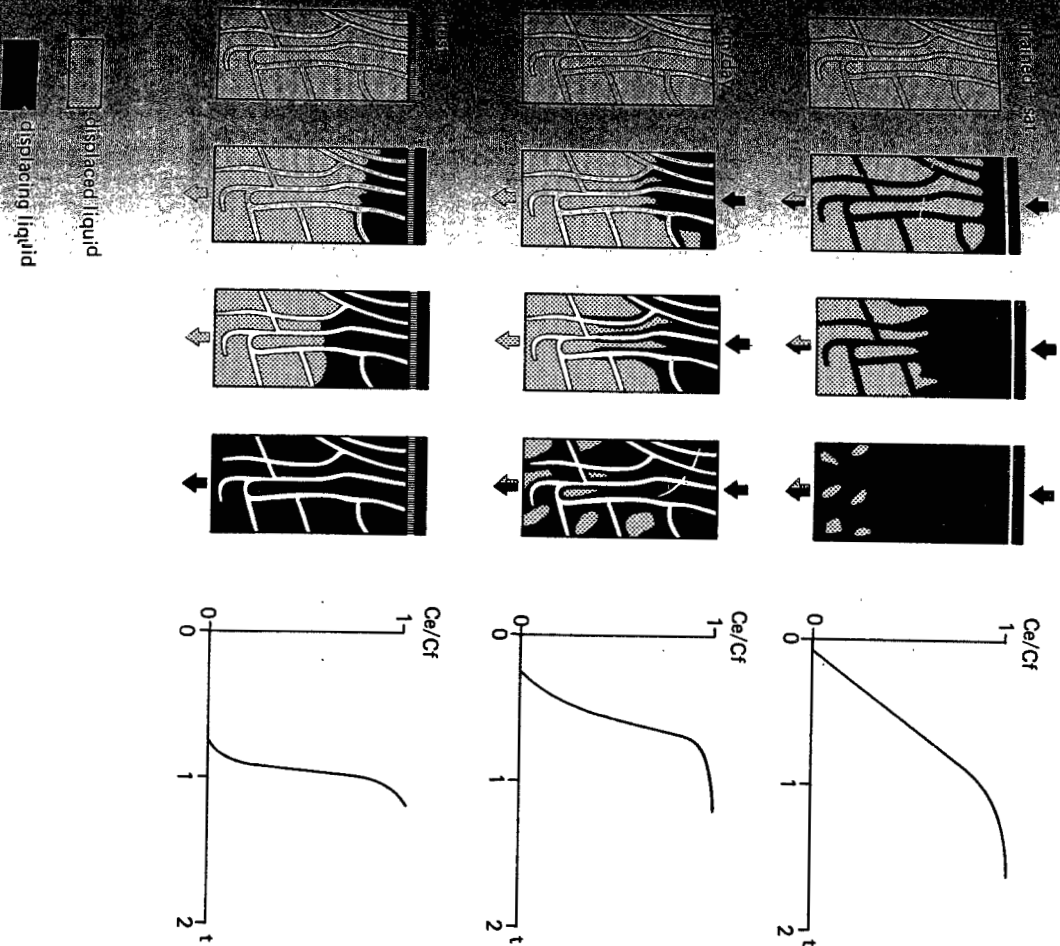


Figure 7. Hydraulic Conductivity Curves

Figure 8. Flow Regimes and Breakthrough Curves for a Pedal Soil Under Different Loading Conditions (t = time; C_f = concentration in feed; and C_e = concentration in effluent)



which has long been operative in this field. If, for example, it were determined that a contact time of two days would suffice for removal of all pathogens in the unsaturated zone, designs could be flexible in light of local site constraints rather than restricted by rigid separation distances, percolation tests, etc.

Another aspect of the contact time and other soil physics concepts described briefly herein is that the various literature citations on travel of pathogens in soils, other than certain well-characterized sands, has little meaning and may contribute to the widely varying and even contradictory nature of the state of the art. For example, studies relating removal to particle sizes of soil may only be valid for sands where piston flow is exhibited. In finer soils with high clay content, macropores could completely reverse the reported relationship between clay content and organism removal because the smaller pores are bypassed under actual conditions. Purely chemical relationships such as pH and ionic strength are not affected by soil hydraulics, but their importance may be diminished when short-circuiting exists. Indeed, it appears that the most important measure of removal is the contact time in the unsaturated zone, and any removal figure cited is useless to other researchers without thorough knowledge of the soil and the hydraulics of flow through it.

Two other public health aspects of conventional systems should also be described in this discussion. These are failures resulting in surfacing and the residuals periodically pumped from septic tanks. Based on present state codes, two types of failures could have uninhibited access to the surface, vents, septic tank effluent could have direct access to the surface, resulting in introduction of pathogens to areas where direct access is permitted. In states where no field vents are permitted, at least in the initial stages of failure, pathogen laden effluent must pass through approximately one foot of soil cover prior to reaching the ground surface. Also, if a level site and level construction can be assumed, the upward loading would be equally distributed over the entire trench surface. This condition continues, the provide some degree of pathogen removal. As the condition continues, the potential for channeling would increase if sufficient head were available between the house and the field, and the failure may approach the situation described for field vent systems. Both of these conditions are depicted in Figure 9.

Periodically, as scum and sludge accumulations reach levels which could impair the performance of the septic tank, pumping of the tank contents must be performed. The pumped liquid, sludge, and scum is usually called "septage". Several investigators have noted the fact that a wide variety of pathogens survive long periods in septic tanks and other sludges. A study by Noland et al. (22), determined the presence of *Salmonella* spp. and *Pseudomonas aeruginosa* in septage along with parasites *Ascaris*, *Ancylostoma*, and other worms. Wolman (23) reported the presence of eggs of *Ascaris*, *Ancylostoma*, and other worms in septage. The World Bank (6) cites *Salmonella typhi* survival of 166 days in a cesspool. Fiege et al. (24) reported *Pseudomonas aeruginosa* in all four septages tested and *Salmonella* spp. in one of four septages. The World Bank (6) noted septage data that indicated two logs of removal for *Schistosoma* eggs in 12 days, one to two year survival of *Trichuris* eggs

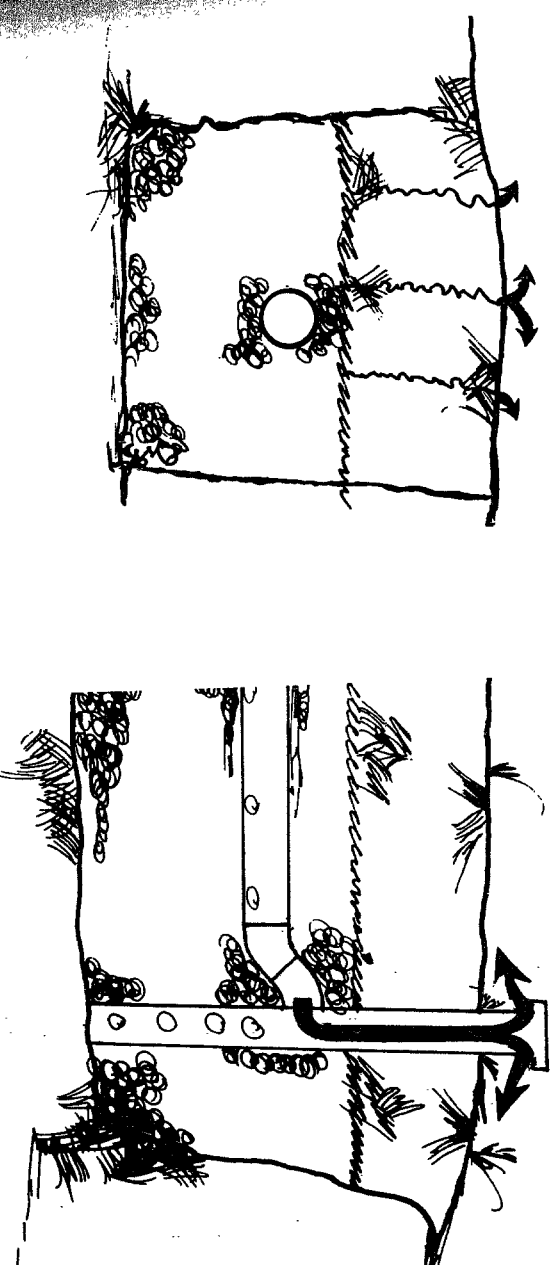


Figure 9. Failure Modes of Two Soil Absorption System Designs

relatively short survival of *Entamoeba histolytica* cysts, *Ancylostoma* eggs present in a density of 28 eggs/gram of dry solids, and *Ascaris* survival of greater than one year.

The significance of these and other data sources must be viewed in the light that any pathogen introduced to a septic tank can be found in the septage, if that introduction occurred within its die-off period prior to pumping. Therefore, the handling and disposal of septage represents a potentially hazardous situation. The disposal of septage to the land has been discussed in several forms and is outside the subject of this discussion. However, epidemiological studies of the disease incidences of septage pumpers would appear to be a subject of potentially fruitful investigation, since this industry is often uncontrolled and handling practices vary widely.

Of the few studies on septage treatment which have included pathogenic investigations, two have involved liming of septage (22)(24). One (22) reported that liming to pH 12.5 reduced *Salmonella* spp. and *Pseudomonas aeruginosa* to undetectable limits and reduced fecal and total coliforms and fecal streptococci by 5, 5, and 3 logs, respectively. However, parasite eggs were still present and viable. The other (24) showed reduction of both the above bacterial pathogens to undetectable levels by liming septage to pH 10.4 to 12.3. The University of Wisconsin study (2) included treatment of septage by formaldehyde at pH 10 and glutaraldehyde at ambient pH. Both techniques reduced *Pseudomonas aeruginosa* counts below detectable levels at aldehyde concentrations of 500 mg/l or more. Reductions of 3 to 4 logs of fecal indicators also occurred with the 500 mg/l dose of glutaraldehyde, but only about 1 log of Po-1 reduction was found. At a 1,000 mg/l glutaraldehyde dose, fecal indicators were removed by greater than four logs, and Po-1 was removed by about three logs in three hours of contact. All tests were performed at 20 C.

In reviewing the information presented herein there is evidence to quantitatively support a case for problems associated with traditional septic tank soil absorption systems from a public health standpoint. The reasons for the shortcomings in traditional onsite technology are primarily related to misapplication of the technology through poor design, poor construction and poor operation and maintenance. These are problems which have led to overcome through research studies of the last ten years, and through communication greatly increased understanding of these problems, and the general population of these results to state and local regulatory agencies which have been identified. However, the basic technology deficiencies which have been identified have spawned studies of alternative onsite systems which will be described by Professor Boyle later in these proceedings.

Health-Related Issues

The major health-related concerns with traditional ST-SAS's have been identified as the initial operational period which poses a threat to groundwater, the periodic problems relating to seepage pumping, and the potential problem of system failure and surfacing of wastewater due to natural clogging or improper design or construction practices. All three of these modes of pathogen transmission have been identified as causes of disease outbreaks. The problem of groundwater pollution is the most prevalent, and is intimately tied to the flow of water through unsaturated soils. Untraced or fresh soil is capable of infiltrating far higher hydraulic loadings than conventional design criteria, generally described by the MSTP (1), anticipate. Although field studies have shown that the loadings of Table 3 are reasonable in practice at equilibrium conditions (2)(19), these conditions do not exist in newly constructed systems. Due to the poor design of the distribution system and the random generation of household wastewaters, serious localized overloading of the soil occurs. This condition, shown in Figure 5, results in flows many times the design flow and provides the impetus for very deep penetration of pathogens below the trench bottom. Although this condition may be transient, i.e., not usually more than six months in duration, a potential microbiological hazard to groundwater exists. By way of an example, it could be assumed that a four-person household with three bedrooms would require anywhere from about 23 m^2 (250 ft^2) of trench bottom area in a coarse sand to about 232 m^2 ($1,000 \text{ ft}^2$) in a relatively fine soil (see Table 3). With the sand, a loading of ten times the design level would easily be accepted by the soil, but would theoretically drive pathogens deeper into the soil. The data of Robeck et al. (17) indicate that this loading would provide at least three logs of removal of Po-1 in 60 cm with similar sands. Cliver (25) showed three logs of removal of Po-1 in 60 cm with similar sands and rates. Therefore, if the required vertical separation between the trench bottom and the groundwater were greater than 60 cm (see Table 1), three logs of poliovirus removal would be assumed possible. However, if an infected individual of the household were to shed 100 grams of feces containing 10^6 PFU of poliovirus (PFU)/gram, dilution in 0.76 cubic meters (average flow for a household) would yield an average wastewater content of about 1.3×10^5 PFU/liter. With adherence to settable and floatable solids, it is reasonable to assume that to one log of removal of virus in the septic tank. Therefore, if greater than four logs of virus were applied to the trench in the above overloaded manner,

approximately one log of virus could potentially reach the groundwater if there were no more than two feet (60 cm) below the trench. Similarly, pathogenic bacteria could penetrate a minimum-depth unsaturated zone, as witnessed by the *Pseudomonas aeruginosa* penetration of 60 cm sand columns cited above (2) (3). Based on the limited data available for parasites, it would appear unlikely that these organisms could penetrate even 60 cm of overloaded sand.

If a finer soil were chosen for the above example and extensive macropore development were extant, the results might be more severe. It would seem plausible that the same distribution shortcoming which caused overloading of 10 percent of the sand trench could cause even greater overloading of the much longer fine soil trench and an overloading of as much as 30 to 40 times the design loading rate. This situation could be quite serious from the standpoint of purification in that the loading would exceed the saturated capacity of the soil in that portion of the trench, resulting in saturated flow through macropores, extremely short contact times, and potentially high numbers of organisms traveling large vertical distances. Although the flow would tend to equalize over most of the trench in clayey soils, macropores may cause significant groundwater contamination if those macropores are continuous through the unsaturated zone. If the example of the macropore effect on contact time used earlier were operative, only 9.6 hours of contact would be available in 60 cm of soil above the groundwater. Although this contact time would appear to be about the same as that of the overloaded sand above, some soil structures with macropores could permit even more pronounced short-circuiting. The experience of Brown et al. (16), in finding coliphage f2 only in the cracked clay soil, verifies the effects of macropores. Potentially, even the larger parasites might penetrate unsaturated soils under such conditions.

The problem of surfacing soil absorption systems has been used by numerous small communities to justify sewers on the basis of imminent health hazards. Although some public health concerns clearly exist and some remedial action is obviously required, there would appear to be a need to evaluate this failure mode as it relates to soil type, cover thickness, venting and stages of failure progression with regard to pathogen movement.

The seepage pumper is exposed to a potentially high pathogenic insult during the course of his activity, even in comparison to sewage treatment plant workers. The disease history of these individuals may provide insight into the need for and mode of institutional control to ensure not only their safety, but that of the homeowner and anyone exposed to the seepage during its subsequent processing. Also, studies of the fate of pathogens in seepage treatment systems are incomplete at this time.

Finally, it would appear that there is a significant need to measure pathogens throughout the onsite treatment and disposal sequence to establish the base conditions and to provide a public health basis for modification of the site evaluation, design, construction, and operation of onsite wastewater treatment and disposal systems. Although many modifications and alternative designs are being developed, the basis for these new approaches has been mostly hydraulic, i.e., to overcome site constraints to disposal. Without sufficient health-related data to demonstrate improved public health aspects,

these modifications are resisted by governmental agencies and potential beneficiaries alike because of incremental construction cost increases, even though long-term savings may be inherent. Health-related data should result in more acceptance of alternative systems which could result in greater protection for rural populations.

Conclusions

1. The transmission of pathogens to groundwater is primarily controlled by the conditions in the unsaturated soil located below the disposal system and above the water table.
2. Most existing data on pathogen removal by soils are of limited use because of a lack of sufficient data on the soils and the flow regimes during the period of testing.
3. There is a need for cooperative efforts between microbiologists and soil physicists to properly characterize and measure the ability of different soils to remove pathogens under various conditions.
4. The transmission of pathogens by means of effluent surfacing and mishandling of septage is less insidious than groundwater contamination by otherwise functioning systems.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

REFERENCES

1. Manual of Septic Tank Practice, USPHS Publication No. 526 (1967).
2. Small Scale Waste Management Project, Management of Small Waste Flows, USEPA Report No. EPA-600/2-78-173 (1978).
3. Ziebell, W.A., Nero, D.H., Deininger, J.F., and McCoy, E., "Use of Bacteria in Assessing Waste Treatment and Soil Disposal Systems," in Proceedings of National Home Sewage Disposal Symposium, ASAE, 58-63 (1975).
4. Green, K.M., Sand Filtration for Virus Purification of Septic Tank Effluent, Ph.D. Thesis, Department of Bacteriology, University of Wisconsin (1976).
5. California State Water Resources Control Board, Rural Wastewater Disposal Alternatives, Draft Report on EPA Grant No. R-805942 (1980).
6. Appropriate Sanitation Alternatives: A Technical and Economic Appraisal, Final Report of World Bank Research Project No. RP0671-46 (1979).
7. Howard, J., and Lloyd B., "Sanitation and Disease in Bangladesh Urban Slums and Refugee Camps," in Progress in Water Technology, Vol. 11, Nos. 1/2, 191-200 (1978).
8. Clarke, N.A., Berg, G., Kabler, P.W., and Chang, S.L., "Human Enteric Viruses in Water: Source, Survival and Removability," in Advances in Water Pollution Research, Vol. 2, ed. by Eckenfelder, W.W., 523-542 (1964).
9. Hatlen, J.B., "Public Health Considerations for On-Site Sewage Disposal," in Proceedings of Northwest On-Site Wastewater Disposal Short Course, ed. by Lenning, D.A., 27-32 (1976).
10. Graun, G.F., "A Review of the Literature 1971-1974 Waterborne Disease Outbreaks," in Jour. Water Pollution Control Fed., Vol. 44, 1175-1182 (1972), Vol. 45, 1265-1277 (1973), Vol. 46, 1384-1395 (1974), Vol. 47, 1566-1581 (1975).
11. Center for Disease Control, Water-Related Disease Outbreaks Annual Summary 1978, U.S. Department of Health and Human Services, Human Health Service Publication No. CDC 80-8385 (1980).

12. Bouma, J., "Evaluation of the Field Percolation Test and an Alternative Procedure to Test Soil Potential for Disposal of Septic Tank Effluent," in Soil Science Society of America Proceedings, Vol. 35, 871-875 (1971).
13. Winneberger, J.T., "Correlations of Three Techniques for Determining Soil Permeability," in Journal of Environmental Health, Vol. 37, No. 2, 108-117 (1974).
14. Bouma, J., Soil Survey and the Study of Water in Unsaturated Soil, Netherlands Soil Survey Institute, Soil Survey Paper No. 13 (1977).
15. Kristiansen, R., "On-Site Disposal of Septic Tank Effluent," in Proceedings of Eighth CIB Triennial Conference, ed. by Norwegian Building Research Institute, Oslo, 370-375 (1980).
16. Brown, K.W., Wolf, H.W., Donnelly, K.C., and Slowey, J.F., "The Movement of Fecal Coliforms and Coliphages Below Septic Lines," Journal of Environmental Quality, Vol. 8, No. 1, 121-125 (1979).
17. Robeck, G.G., Clarke, N.A., and Dostal, K.A., "Effectiveness of Water Treatment Processes in Virus Removal," in Journal AWWA, Vol. 54, 1975-1292 (1962).
18. Cram, E.B., "The Effect of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage," in Sewage Works Journal, Vol. 15, 1119-1138 (1943).
19. Bouma, J., Ziebell, W.A., Walker, W.G., Olcott, P.G., McCoy, E., and Hole, F.D., Soil Absorption of Septic Tank Effluent, University of Wisconsin - Extension Circular No. 20 (1972).
20. Bouma, J., unpublished memoranda to author.
21. Gerba, C.P., Wallis, C., and Melnik, J.L., "Fate of Wastewater Bacteria and Viruses in Soil," in ASCE Journal of Irrigation and Drainage Div., Vol. 101, IR3, 157-174 (1975).
22. Noland, R.F., Edwards, J.D., and Kipp, M., Full-Scale Demonstration of Lime Stabilization, EPA Report No. EPA-600/2-78-171 (1978).
23. Wolman, A., "Public Health Aspects of Land Utilization of Wastewater Effluents and Sludges," in Journal WPCF, Vol. 49, 2211-2218 (1977).
24. Feige, W.A., Oppelt, E.T., and Kreissl, J.F., An Alternative Septage Treatment Method: Lime Stabilization/Sand-Bed Dewatering, USEPA Report No. EPA-600/2-75-036 (1975).
25. Green, K.M., and Cliver, D.O., "Removal of Virus from Septic Tank Effluent by Sand Columns," in Proceedings of National Home Sewage Disposal Symposium, ASAE, 137-143 (1975).

CURRENT PRACTICES - SUBSURFACE DISPOSAL: JAMES KREISSL

TRANSCRIPT OF QUESTIONS/RESPONSES/COMMENTS

Q: Rohlich

I have one question. To what extent have there been determinations of the hydraulic characteristics of septic tanks since you continually hear about 2 to 3 days retention?

A: Kreissl

The theoretical detention time of a septic tank prior to accumulation of scum and sludge is generally 3 to 5 days. Typically, discrete wastewater generation events are less than 5 percent of the total tank volume. Therefore, the long detention time tends to obfuscate the poor hydraulic design of the septic tank. To my knowledge, no dye studies have been performed. However, studies of tank suspended solids removal efficiency done by USPHS and the Wisconsin small scale waste management staff indicated the benefits of compartmentalization. There is a real advantage in the multiple compartment tank because it would cut down any potential short-circuiting without increasing overall tank volume requirements.

Q: Rohlich

Well, I don't want to take the time to argue with you on that point, but even in the design of gravity oil-water separators, for example, and other similar units, the problem is that actual flow-through time is often much less than the theoretical detention time.

A: Kreissl

Absolutely' correct, but the point that I am making is that since the theoretical detention time is so long, the actual detention time would still be in excess of that for primary clarifiers. However, your point is well taken in that improved

septic tank hydraulics has not been fully explored.

Q: Morrison

Jim, would you like to comment on the fact that a great number of these systems are in second homes, e.g., recreational homes, in which your hydraulic loading runs through an annual cycle of peaks and valleys. Is there any hope of getting a system which will adjust to this kind of difficulty pattern.

A: Kreissl

Quite obviously, I think, because of its non-mechanical nature, the septic tank-soil absorption system is probably a good approach. From the standpoint of the soil, there are significant benefits to a long period without use. Soil infiltration capacity becomes regenerated during periods of non-use. From the tank standpoint, because of its non-mechanical nature, it is least affected by that type of wastewater generation pattern. Many mechanical units are not appropriate to long periods of non-use. In addition to performance deterioration, increased maintenance often results from lack of use. So I think pretreatment simplicity is beneficial. Most importantly, the soil benefits from that type of use pattern.

Q: Gregg

This may be getting a little bit ahead of the schedule, but can you give me some idea of what percent of the outbreaks of disease that have been attributed to septic tank malfunctioning have been investigated, so that you feel reasonably sure what part of the system may be at fault.

A: Kreissl

In my paper I did present some data on this topic. The difficulty is that there are many outbreaks, as you know much better than I, where the source was not identifiable. The waterborne disease outbreaks where the source was identified in the period of 1970 through 1974 showed that less than 10 percent of the total were attributed to septic tank-soil absorption systems. Now, it is possible that these systems actually accounted for more than 10 percent of the outbreaks had the data been more complete. I noticed in the 1978 report from CDC that none of the 1978 outbreaks were identified as being from septic tank-soil absorption system (ST-SAS) sources. According to the CDC data for 1970 to 1974, the ten outbreaks caused by ST-SAS sources resulted from, in all but one case, etiological agents penetrating the unsaturated soil to the ground water with subsequent travel with the ground water to a drinking water supply. In the other case the system failed, surfaced, and overflowed down a hill to a well which was poorly sealed from surface pollution.

Q: Lennette

In discussing Figure 3 of your paper you mentioned something about one log reduction. Is this an across the board figure or a specific one?

A: Kreissl

That is just an average figure. In the case of Ascaris ova, you would expect to get two to three logs or more. In the case of a virus you may get negligible removal. My general statement is that you could not count on complete removal of any organism. The tank itself incorporates too many negative factors. As Dr. Rohlich points out, there is potential for significant short-circuiting. You also have digestion of solids which occurs in warm weather. These factors would negate consistently good removals of any organism.

Q: Lennette

Well, a reduction of one log is a 90 percent reduction, which to the engineers and chemists I guess is meaningful. To the microbiologist, however, that is not too meaningful. It is the absolute numbers which count.

A: Kreissl

I discussed this situation with Dr. Akin during the period I spent preparing the paper. I wish we had the data to properly calculate allowable pathogen levels at specific locations in the treatment systems for individual homes to permit control measures; something on the order of what Foster and Engelbrecht attempted, but with more accuracy.

Q: Pipes

I wonder if you could be more specific about the need for more information on pathogen removal. Do you have any specific pathogens in mind?

A: Kreissl

No, I don't. While rooting through the literature for the last few months, I found that there is very little definitive information which is useful to locations other than those where data were generated. For example, Cram's work on Ascaris in the 30's seemed to be most applicable, as did the Salmonella studies of Green and Beard of the same era. The lack of utility of many more recent studies to me may have related to my lack of ability to work in the microbiological literature, but I could not use some more recent studies because of a lack of necessary data on other controlling factors. The types of organisms in most need of study will be determined by groups such as yourselves. CDC documents the causative agents of waterborne disease outbreaks. Those are probably the ones with which to start. My feeling is that we just don't have useful information which can be applied to new sites for engineering analysis. The needed data must not only enumerate organisms, but it must also document hydraulic conditions, soil types and other physical and chemical phenomena. At present there are dots all over the place on organism removal at different locations. What we don't have is the scientific basis for putting them into a matrix that means something.